CHAPTER 3

DG LOCATION AND PROTECTION RELAYS USING MAS TO IMPROVE RELIABILITY ASSESSMENT

3.1 INTRODUCTION

This Chapter describes the methods and variables used in order to carry out the research and simulated procedure. The study is conducted in two stages; the first stage is the grounding analysis for a new technique for selecting the best DG location by using MAS and secondly a new index reliability for determining relay operating time based on MAS. The implementation of the proposed methods for real time data is also elaborated.

3.2 DISTRIBUTED GENERATOR (DG)

DG provides many advantages in term of improvements in losses and reliability, or both (Yousefian and Monsef, 2011). In addition, there are many DGs locations which can lead to minimize fault current in the event of faults and provide the necessary effective grounding to solve bus voltage problems when unfault phases over voltage in bus are encountered.

3.2.1 System Effectively Grounded with DG

When DGs are connected into the distribution power grid, the grounding methods should be taken into account. There are many types of grounding, e.g., solid grounding, resistance or reactance grounding and isolated grounding. In the last decade, the phrase of “solidly grounded” has replaced to the newer “effectively grounded” for a reason of no auxiliary grounding devices (resistors, reactors, neutralizers, etc.) that are ordinarily required. In effectively grounded system, all faults including grounds must be cleared by opening the line. The ground fault currents close to the grounding point are high, in some cases exceeding the three phase short circuit currents. In a few instances, higher interrupting capacity breakers may be required over that necessary for the three-phase short-circuit interruption. The higher currents also produce more conductors burning and result in lower positive-sequence voltages with a tendency toward a lower stability limit for line-to-ground faults. In addition, the effectively grounded systems are less expensive than any other type of grounding.

For using a DG without a transformer, special attention should be paid to the zero sequence impedance design so that effective ground can be provided. Unlike the DG with a transformer providing the effective ground passively, the DG without a transformer must shape the zero sequence impedance characteristic using an active control approach (Kroposki, 2003). For a system effectively grounded, all system points or in specified portion, the ratio of zero-sequence reactance to positive-sequence reactance is not greater than "three" while the ratio of zero-sequence resistance to positive-sequence reactance is not greater than "one" for any operational condition, the system may be considered as effectively grounded (Nelson and John, 2003) when the following conditions in Equation (3.1) are met:

$$1 < \frac{X_0}{X_1} < 3 \quad \& \quad 0 < \frac{R_0}{X_1} < 1 \tag{3.1}$$

where, X_1 is positive sequence reactance, X_0 is zero sequence reactance and R_0 = zero sequence resistance.

The third condition is unfaulted phases may be subjected to over-voltages in which the absolute value of overvoltage in per unit is given as in the following Equation (3.2) (Balakrishnan, 2008):

$$V_D = \sqrt{\left(\frac{\sqrt{3}}{2}\right)^2 + \left(\frac{1}{2} + \frac{\left(\frac{X_0}{X_1}\right)-1}{\left(\frac{X_0}{X_1}\right)+2}\right)} \tag{3.2}$$

where; V_D is overvoltage during single line to ground fault (L-G) in which voltage one phase varies from 0.866 pu to 1.732 pu.

For a power system with *m*-buses, the bus relation between voltage and current may be represented as a bus impedance matrix given in Equation (3.3). Unlike the bus admittance matrix, the bus impedance matrix cannot be formed by simple examination of the network circuit. It can be formed by direct inversion of the admittance matrix, open circuit testing, and step-by-step formation or graph theory (Saadat, 2004).

$$\begin{vmatrix} V_1 \\ \vdots \\ V_m \end{vmatrix} = \begin{vmatrix} Z_{11} & \cdots & Z_{1m} \\ \vdots & \ddots & \vdots \\ Z_{m1} & \cdots & Z_{mm} \end{vmatrix} \begin{vmatrix} I_1 \\ \vdots \\ I_m \end{vmatrix} \tag{3.3}$$

where, $Z_{11} = R_{11} + jX_{11}$. By considering the faulty case as given in L-G fault for bus *m*, the sequential components of the line-to-ground voltages at any bus *m* during a fault at bus *n* are given by Equation (3.4) (Appendix C).

$$\begin{bmatrix} V_{m-0} \\ V_{m-1} \\ V_{m-2} \end{bmatrix} = \begin{bmatrix} 0 \\ V_F \\ 0 \end{bmatrix} - \begin{bmatrix} Z_{mn-0} & 0 & 0 \\ 0 & Z_{mn-1} & 0 \\ 0 & 0 & Z_{mn-2} \end{bmatrix} \begin{bmatrix} I_{n-0} \\ I_{n-1} \\ I_{n-2} \end{bmatrix} \tag{3.4}$$

Therefore, the short-circuit calculations with a bus impedance matrix of symmetrical components of a fault current (single line to ground fault) can be computed as Equation (3.5) (Appendix C).

$$I_m^0 = I_m^1 = I_m^2 = \frac{V_F}{Z_{mm}^0 + Z_{mm}^1 + Z_{mm}^2 + 3Z_F} \tag{3.5}$$

where, Z^1_{mm} , Z^2_{mm} *and* Z^0_{mm} are the diagonal elements in the *m-axis* of the corresponding impedance matrix , Z_F is a fault impedance and V_F is the pre-fault voltage at bus *m.*